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Abstract

STATISTICAL THEORY OF NEUTRON CHAIN REACTIONS

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A statistical theory is developed for the chain reactions in nuclear reactors. The probability distribution function /PDF/ for the number of neutrons in a given state is derived with assumptions of quite general character. From the PDF the fundamental equation for the generating function is obtained permitting the calculation of the expectation value and the variance of the neutron density. Equations are derived for the PDF of the number of fissions and neutrons counted during a given time-interval. Several limit theorems are derived for the generating functions. These theorems are important in various applications of the theory. The multi-group approximation is introduced into the framework of the statistical theory.

In the paper several applications are illustrated. The fluctuation of the neutron yield in pulsed fast reactors is considered and the theory of the prompt neutron period measurements in thermal reactors is developed on the base of neutron density fluctuations.

In the former case calculations are made in one-group approximation and the time dependence of the neutron density

fluctuations is computed for different reactivity changes. A simple form of time-dependence on reactivity is chosen. The reactivity of the system at the start of the run is assumed to be negative. Reactivity then increases to a definite positive value, and decreases to its original negative value. It is shown that the number of neutrons and fissions in a simple burst fluctuates strongly even if the average number of pulse-initiating neutrons is relatively high.

In the latter case the effect of the delayed neutrons on the accuracy of measurements is analysed and the correlation between the numbers of neutrons counted in consecutive time intervals is examined. Spatial fluctuations of neutron density are also studied and on the base of this study a new method is proposed for the criticality parameter measurements. As a result of theoretical considerations it is shown that the correlation method can be used in the case of thermal reactors too, provided the average neutron lifetime is not larger than about 10^{-4} sec. The theoretical basis of the "Zero Probability Method" is given and a mathematical procedure is derived for the determination of the prompt period with help of this method.

Finally a review is given on the latest results of the statistical theory of neutron chain reactions.